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DROP-BALL IMPACT RESISTANCE OF OPHTHALMIC LENSES--COMPARISON OF--ETC(U)

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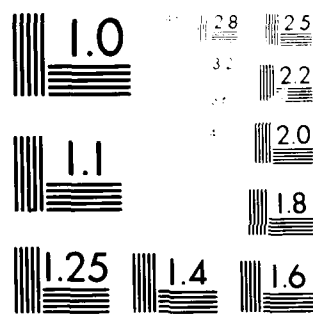
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DROP-BALL IMPACT RESISTANCE OF OPHTHALMIC LENSES

Comparison of Tint, Material, Treatment Process, and Drilling

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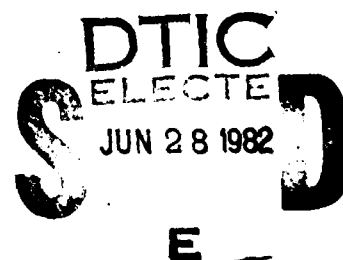
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May 1982

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USAF SCHOOL OF AEROSPACE MEDICINE

Aerospace Medical Division (AFSC)

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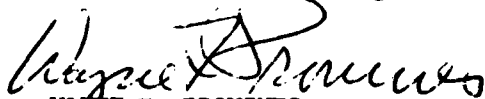
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This technical report has been reviewed and is approved for publication.


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DROP-BALL IMPACT RESISTANCE OF OPHTHALMIC LENSES
Comparison of Tint, Material, Treatment Process, and Drilling

INTRODUCTION

The Food and Drug Administration (FDA) ruled that, as of 1 January 1972, all prescription ophthalmic lenses were to be impact resistant (1). According to the regulation, impact resistance is the ability of a lens to survive the fall of a 15.9 mm (5/8-in) steel ball from a height of 127 cm (50 in.) into the front surface of the lens. To induce impact resistance in a glass lens, a heat or chemical surface-hardening process is employed.

The American National Standards Institute (ANSI) set forth exceptions to this testing (2). Special corrective glass lenses should be treated, but may be waived from impact testing. On the basis of batch testing, laminated, plastic, and raised-edge multifocal lenses may be certified by the manufacturer as conforming to initial design testing. Nonimpact-resistant lenses may be substituted if the physician or optometrist determines that only a nonimpact-resistant lens will fulfill the patient's visual requirements. Both the patient and the optical fabricator must be informed of the use of a nonimpact-resistant lens.

The U.S. Air Force has contributed to ophthalmic lens testing (3-9) and continues to stay current in impact-resistant eyewear. Eye protection is required on a spectrum extending from aircrew combat to recreational sports and hobbies. In 1980, approximately 85,000 prescription glasses were issued to active duty Air Force personnel. This total did not include flight sunglasses and industrial safety glasses.

The purpose of our study was to compare: impact resistance of both tinted and clear ophthalmic lenses of selected materials; and hardening treatments. Emphasis was placed upon the effects of lens drilling for rimless mountings. The Air Force does not issue rimless frames; however, the need exists to develop corrective lens mountings compatible with aircrew protective headgear. The use of mountings requiring drilled lenses may be required to satisfy equipment integration design. The need for unrestricted peripheral vision would also be served if supporting eyewires could be eliminated.

MATERIALS, EQUIPMENT, AND PROCEDURES

The Optical Research Unit of the Ophthalmology Branch, USAF School of Aerospace Medicine, fabricated 4,172 prescription lenses from stock purchased from several major American manufacturers. A large sampling of lenses was available from discarded small blank stock. Powers ranged in sphere components from +5.50 to -6.00 diopters. Maximum cylinder component was +6.00 diopters. Center thickness (CT) ranged from 1.1 to 5.2 mm. Lenses were of crown glass and plastic (CR-39) materials. Approximately half of the lenses of each group were clear, and half were of neutral tint of $31 \pm 3\%$ light transmissivity. Plastic lenses were dyed with Uni-Lite Lite-Fast basic maroon dye 2079 to obtain neutral density tint. All lenses were edged on a bevel edger (AIT brand)

to a 48-mm size in a 404-4 shape. Each lens was then hand-beveled for a smooth-finish safety edge. Every other lens in each group was drilled for rimless mounting holes, by use of a Dumoke drill press with a diamond bit turning at 17,000 rpm.

The clear-glass and the tinted-glass lens groups were each divided into three subgroups: The first was heat-treated with a Bausch & Lomb lens heat-treating unit. The second was chemically treated, by means of a Kirk chemical lens-hardening unit. Hardening procedures specified for these units were carefully observed. The third subgroup received no hardening treatment. None of the plastic lenses were treated.

Listed in Table 1 are the number of lenses in each group, as well as the descriptive statistics for center thickness and spherical equivalence. Spherical equivalence is obtained by algebraic addition of the sphere and one-half of the cylinder components of a lens prescription. This unit eliminates the cumbersome use of both sphere and cylinder powers. Within each lens group, the drilled and nondrilled lenses have very similar distributions with respect to center thickness and spherical equivalence. Some deviation does exist in the untreated glass lens groups; however, these lenses are not our primary concern.

All lenses were subjected to drop-ball testing, as specified in the ANSI 780.1-1979 test procedure. An unmodified Bausch & Lomb drop-ball test device was used. Each lens was repeatedly drop-ball impacted until the lens fractured or, if it remained intact, until it had been impacted by a total of 20 drops (4).

RESULTS

Shown in Table 2 is the percentage of broken lenses in each group, according to thickness and on an overall basis. Note that the "Total" column includes lenses of only 2.1 mm CT and greater. ANSI specifies that all lenses must have a minimum thickness of 2.2 mm. Therefore, only lenses which are representative of those commonly dispensed are considered in our primary statistical analyses. The value of 2.1 mm minimum CT was chosen for CT quality-control compensation in production operations. Shown in Table 2 are results of Chi-Square tests performed on each lens group to determine if the total breakage of the drilled lenses differed from that of the nondrilled lenses. Chi-Square tests were also performed, to compare the various treated glass and plastic lens groups for differences in drilled lens breakage. These results are not given in Table 2, but are reported in the two following sections.

Lenses of 2.1 mm CT or Greater

Among the clear treated-glass lenses (heat and chemical), the drilled lenses showed significantly more breakage ($p=.001$) than the nondrilled lenses. The heat-treated lenses showed the greatest difference. Among the clear nontreated-glass lenses, near total breakage occurred in both groups.

Among the tinted treated-glass lenses, the pattern was mixed. The chemical-treated drilled lenses showed significantly more breakage than the nondrilled ($p=.005$). No statistical difference in breakage was found between drilled and nondrilled heat-treated lenses. Among the nontreated tinted-glass lenses, the breakage was near total for nondrilled lenses. Testing of drilled

tinted lenses was discontinued after the first ten shattered upon initial impact.

In the plastic lenses, no significant difference occurred among drilled and nondrilled lenses, clear or tinted.

In our comparisons of the drilled lenses across the groups, we found the percent of breakage in the clear chemical treated-glass lens group to be less than that in the clear heat treated-glass lens group ($p < .001$). In turn, the percent of breakage in the two tinted treated-glass lens groups was less than that in the two clear treated-glass lens groups ($p < .001$ in each case). Finally, less breakage occurred in the two plastic lens groups than in the two tinted treated-glass lens groups ($p < .025$ in each case), with one exception: clear plastic and tinted chemical treated-glass lenses did not differ statistically. (The appropriate percentages are in the "Total" column of Table 2.)

Lenses of 2.0 mm CT or Less

Impact-resistance results among lenses of 2.0 mm CT or less were somewhat unexpected. The clear-glass lenses are unremarkable, the drilled showing greater breakage than the nondrilled. This pattern is also evident among the plastic lenses, the thin drilled lenses (both clear and tinted) showing substantial breakage numbers. The thin, treated-glass tinted lenses reveal a rather surprising phenomenon. The drilled lenses unexpectedly show significantly less breakage than the nondrilled lenses. Recheck of our work revealed no errors in our recording system or in the subsequent data processing. At present, we have found no inherent reason for these results.

DISCUSSION

The data from this study show that, generally, drilling of ophthalmic lenses for rimless mountings reduces high-mass, low-velocity impact resistance. Exceptions are evident among plastic and tinted-glass materials. The tinted-glass results suggest that chemicals added to glass melt batches for tinting purposes may also alter the impact resistance of the finished lenses.

Direct comparison of materials and hardening methods on drilled lenses indicates that plastic of 2.1 mm CT or greater is the least vulnerable to breakage; thus, plastic appears to be the lens material of choice. However, the Air Force has been reluctant to authorize extensive use of plastic lenses because of the problems of base curve warpage and poor surface abrasion resistance, which result in excessive replacement demands by the wearers. Polycarbonate prescription lenses have greater impact resistance, but very poor abrasion resistance has limited their use. The Research Optical Laboratory, Ophthalmology Branch, USAF School of Aerospace Medicine, is now conducting a field-use study of hard-coated polycarbonate prescription lenses. Use of plastic may not be advisable in dusty field environments where little protective care can be expected.

Drilled, tinted hardened-glass lenses of 2.1 mm CT or greater appear to have more impact resistance than drilled, clear hardened-glass lenses. The breakage rate (11%) of the tinted chemical-hardened lenses is particularly noteworthy. Such a lens shows promise of acceptability in the drilled state.

TABLE 2. PERCENTAGE OF BROKEN LENSES IN EACH LENS GROUP
(separated by center thickness)

Lens Group	Center Thickness		Center Thickness					Total of		
	22.0 mm	P	2.1-2.5	2.6-3.0	3.1-3.5	3.6-4.0	>4.0	CT ≥2.1	P	
Glass Clear										
Chem-tr										
drilled	31(4/13)	<.10	47(62/133)	41(18/44)	16(7/43)	38(12/32)	20(5/25)	38(104/277)	<.001	
nondrilled	9(2/23)		15(18/119)	11(5/45)	22(9/40)	24(8/33)	3(1/30)	15(41/267)		
Heat-tr										
drilled	91(20/22)	<.025	86(114/132)	58(26/45)	35(14/40)	11(4/36)	0(0/11)	60(158/264)	<.001	
nondrilled	60(9/15)		4(6/150)	0(0/43)	0(0/35)	0(0/35)	0(0/15)	2(6/278)		
Nontr										
drilled	100(5/5)	NT	100(36/36)	-----	-----	100(9/9)	-----	100(45/45)	NS	
nondrilled	100(11/11)		98(109/111)	98(47/48)	94(44/47)	86(32/37)	92(34/37)	95(266/280)		
Glass Tinted										
Chem-tr										
drilled	26(28/107)	<.025	20(4/20)	9(6/66)	14(5/36)	7(3/42)	11(2/18)	11(20/182)	<.005	
nondrilled	42(44/106)		10(3/30)	1(1/70)	0(0/41)	3(1/37)	0(0/16)	3(5/194)		
Heat-tr										
drilled	14(14/98)	<.001	15(5/33)	24(18/75)	12(4/33)	14(6/42)	0(0/16)	17(33/199)	NS	
nondrilled	42(44/104)		16(4/25)	18(14/76)	11(4/36)	0(0/33)	0(0/19)	12(22/189)		
Nontr										
drilled	no data	NT	-----	-----	-----	-----	-----	-----	NT	
nondrilled	95(95/100)		100(17/17)	92(71/77)	95(36/38)	95(41/43)	100(19/19)	95(184/194)		
Plastic Clear										
			2.1-2.2	2.3-2.4	>2.4					
drilled	27(64/239)	<.001	6(2/35)	6(1/17)	0(0/9)			5(3/61)	NS	
nondrilled	8(21/235)		10(2/20)	0(0/14)	0(0/10)			5(2/44)		
Plastic Tinted										
drilled	20(47/231)	<.001	3(1/35)	0(0/21)	0(0/13)			1(1/69)	NS	
nondrilled	9(23/263)		0(0/21)	0(0/5)	0(0/11)			0(0/37)		

Note:

1. First number is percentage of broken lenses. Numbers in parentheses are the number broken over the total number tested.
2. P is the significance level associated with the two-tailed test to determine whether the total percentage broken was different in the drilled lenses than in the nondrilled lenses. (Chi-Square tests for independence were used.)

Abbreviations: chem-tr = chemically treated
 heat-tr = heat treated
 nontr = nontreated
 NS = not significant at .10 level
 NT = not tested

Currently, 20% of USAF pilots and 50% of USAF navigators must wear corrective lenses while flying (10). The task of integrating ophthalmic lenses with the proposed protective equipment is increasingly difficult. Clear-glass lenses which could be drilled and still afford acceptable impact resistance would provide additional lens-integration design alternatives.

The drilling of ophthalmic lenses for rimless mountings reduces impact resistance, with certain exceptions, among plastic and tinted lenses. Chemicals added to glass melts for tinting appear to increase impact resistance of drilled lenses. Tinted hardened-glass lenses of 2.0 mm CT or less behave unexpectedly, with greater breakage among the nondrilled than the drilled lenses.

RECOMMENDATIONS

Nontinting chemical additives that might add impact resistance to finished ophthalmic lenses should be investigated. The impact resistance of drilled hardened-glass lenses to high-speed, low-mass impact should be evaluated. Whether or not lens warpage occurs in frame-mounted drilled plastic lenses should be determined.

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